PENNSTATE

Large Area Neutron Detectors

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Acknowledgements:

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Large Area Neutron Detectors

Goal: to develop a cost-effective neutron detector design to populate large area of CNCS at SNS (~100 m^2)

Motivation: ~3000 commercial LPSDs, cost with mounting racks ~$7M, our budget is $2M)

Required performance

- Resolution 1 in x 1 in
- Count rate up to 10^5 events/sec (Roadmap: 1cm x 1cm, $2x10^7$ events/sec)

Solution

- Position-sensitive area detectors
- Common gas volume (gas flow techniques)

- Proposed Dec 2001
- Approved CNCS Review Committee Jan 2002
- Started Feb 2003

Large Area Neutron Detectors

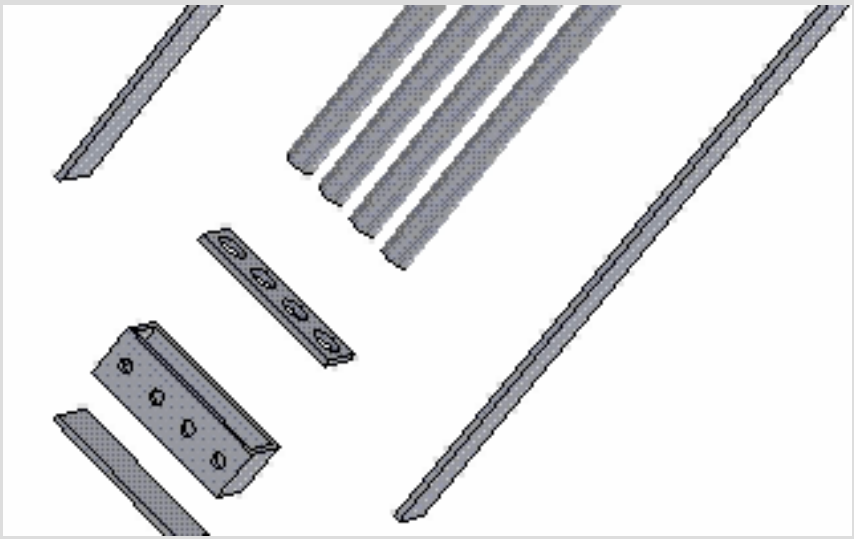
Prototype Designs

- Banks of Linear Position Sensitive Detectors
- Flat window detectors
- Multi-Pixel Detectors

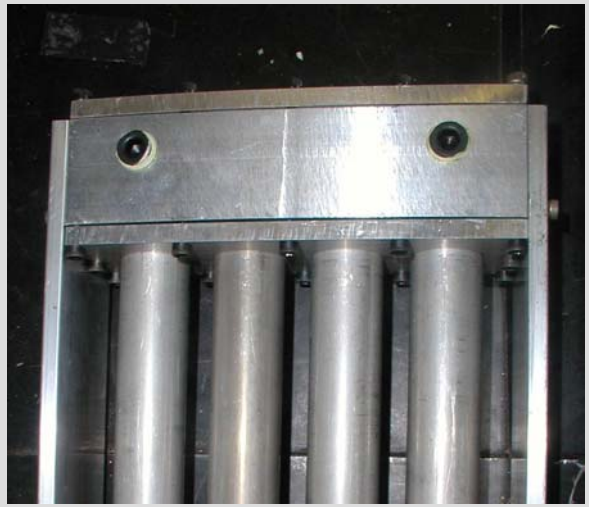
Methods

- ^{3}He + quenching gas for detector
- Common gas volume
- Option for gas purification (if needed)

Prototype Multi-Tube LPSD

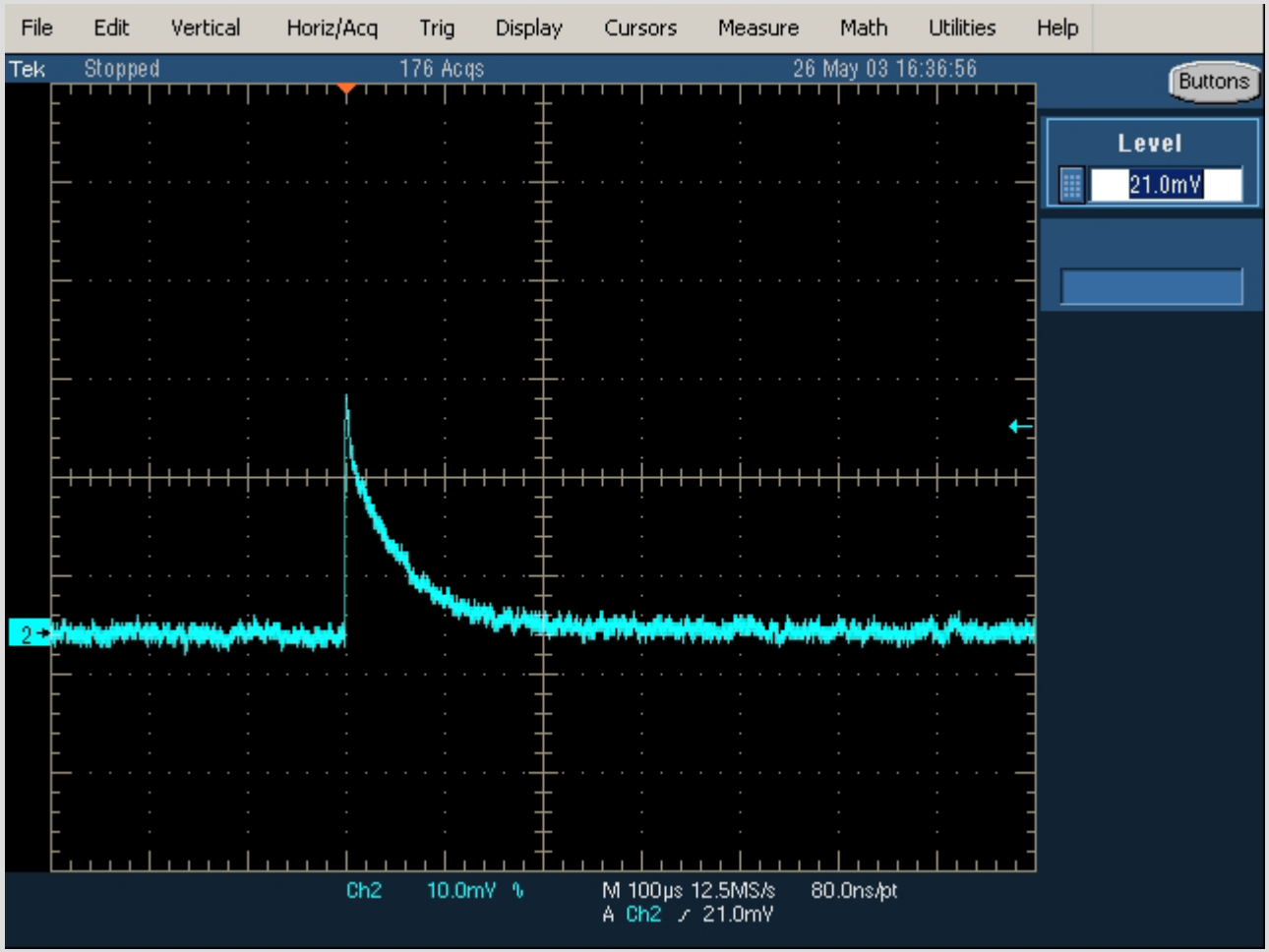


Detector scheme



Prototype LPSD

Prototype Multi-Tube LPSD



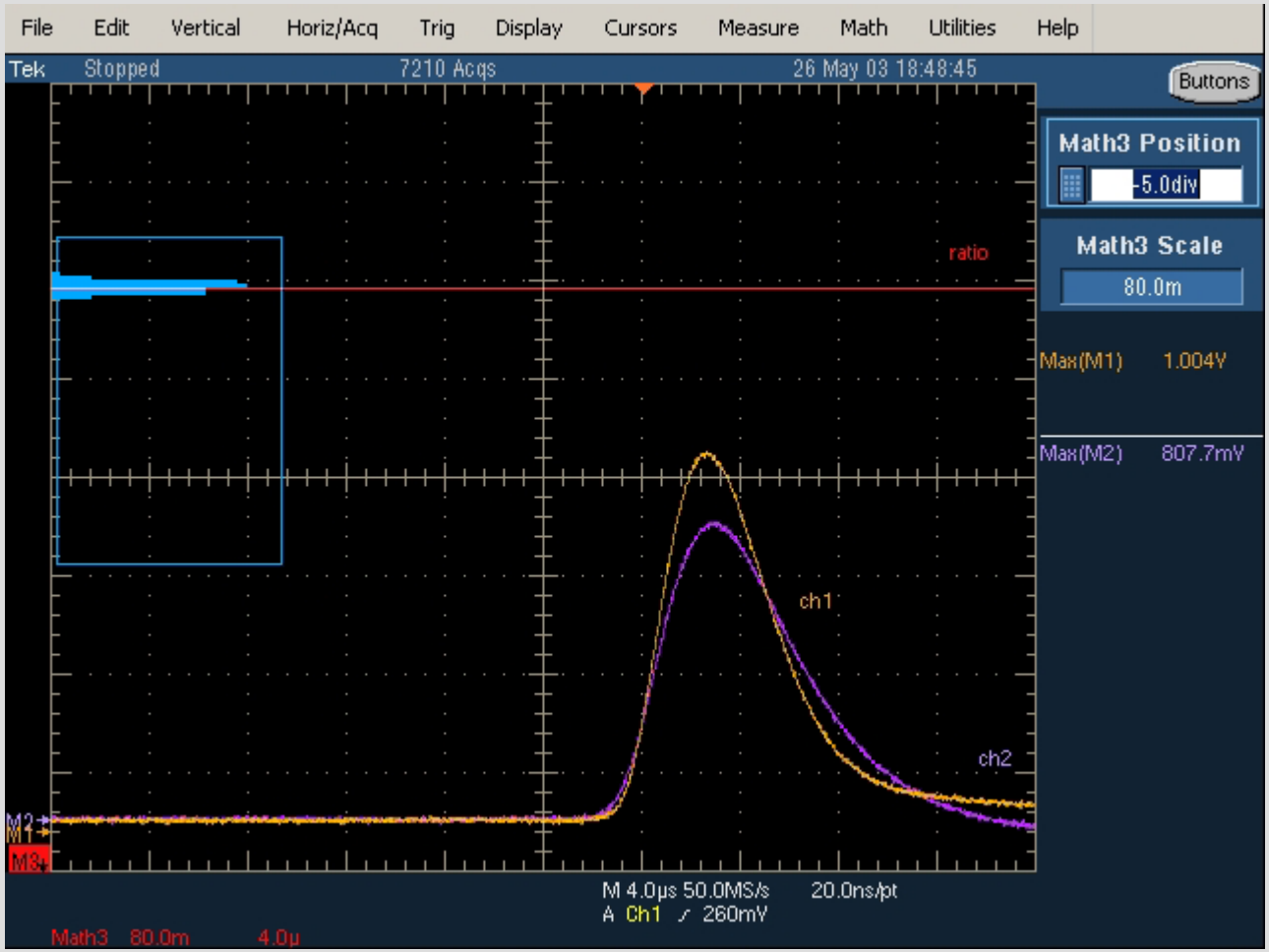
Operation parameters

HV: +1200 V

Gas: 3 atm ^{3}He + 0.3 atm propane

Preamplifier signal

Prototype Multi-Tube LPSD



Operation parameters

HV: +1200 V

Gas: 3 atm ^{3}He + 0.3 atm propane

Amplifier signals

Charge division scheme

Position information

Lifetime Considerations

Lifetime limiting factors

- Loss of pressure
- Impurities from outgassing
- Polymerization of quenching gas
- Etching (coating) of wire

• Loss of gas charge (leakage)

5% drop in efficiency in 10 years is satisfactory for practical applications.

Parker O-ring Catalogue, p.3-21: Leakage through the seal is $\mathbf{L = 0.7\ F\ D\ P\ Q\ (1\text{-}S)^2}$

For helium under the pressure 6 atm and neoprene O-ring with squeeze 0.5, gas permeability ~6×10^{-8} std cc / cm^2 sec bar, the leak rate of the seal is L~9.3×10^{-8} std cc / sec. For four-tube array, eight O-rings L~ 10^{-6} std cc / sec. Total tube charge is 24 liter atm, or 24000 std cc. 5% change of this volume is 1200 std cc. Time required for this change is 1.2×10^9 sec or **38 years**.

• Contamination from outgassing

Outgassing level for four-tube prototype (area 1600 cm^2):

During 10 years - **1%** of impurities (47 Torr). It can be removed from gas mixture by purification.

Cost Considerations

Commercial LPSD

- Individual units
- Sealed design
- Welded, non-repairable

Baseline plan for CNCS

Detector parameters

- Area: 1 x 0.025 m^2
- Cost: ~$2,000 with mounting
- Cost per area: $2,000/0.025 or ~ε **$80,000/m^2**

➢ Cost of 1m 1" LPSD ~$1,700
➢ Cost of ^{3}He ~$125 lit atm
➢ 6 atm, 0.5 lit ~ $375 or 22% of total cost

Multi-Tube LPSD

- Common gas volume for several tubes
- Modular design, can be disassembled and maintained / repaired

Detector parameters

- Area: 8 x 0.025 m^2
- Cost: ~$4,600 with mounting
- Cost per area: $4,600/0.2 or ~ε **$23,000/m^2**

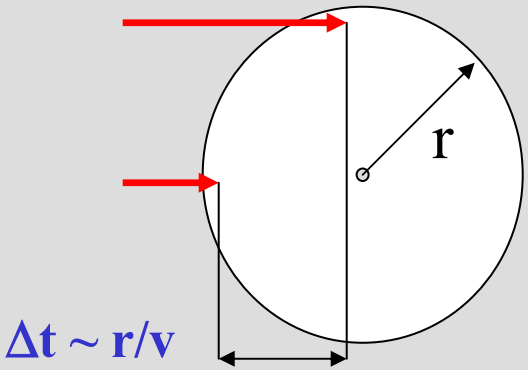
➢ Cost of detector parts ~$1,600
➢ Cost of ^{3}He ~$125 lit atm
➢ 6 atm, 4 lit ~ $3,000 or 65% of total cost

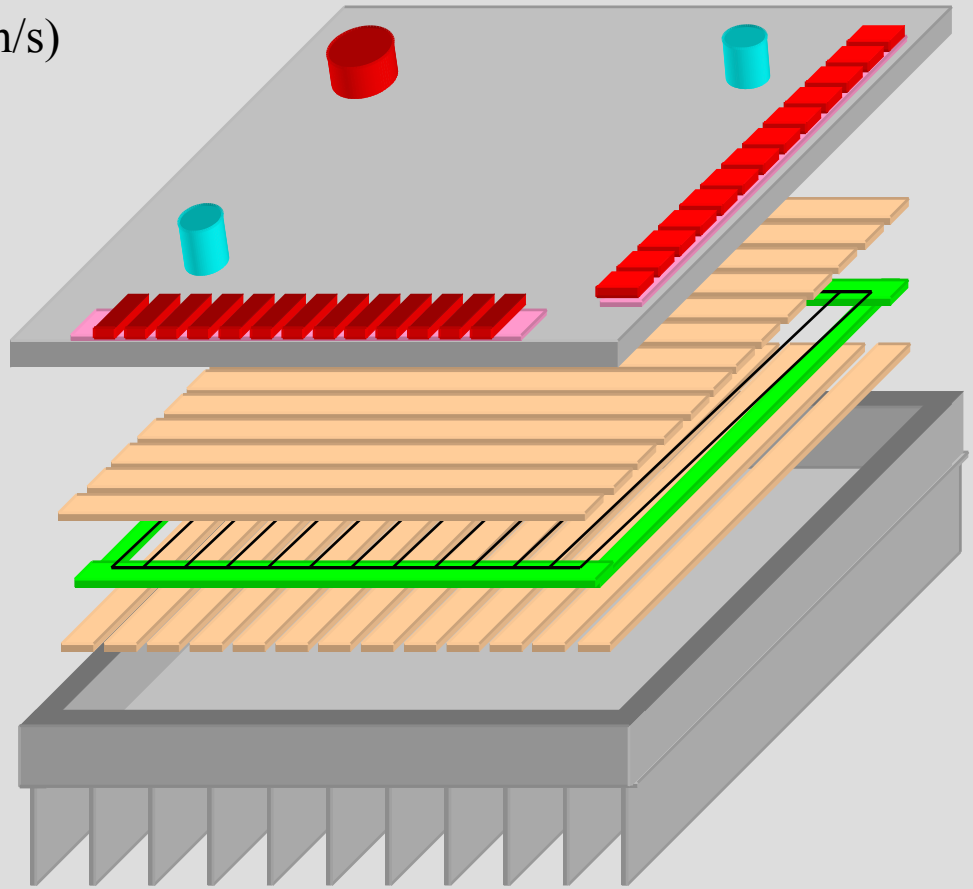
Multi-Tube Detector Array

Flat Window Detector

Tube detectors

➢ Timing problems for slow neutrons (v ~ m/s)
because tube is curved



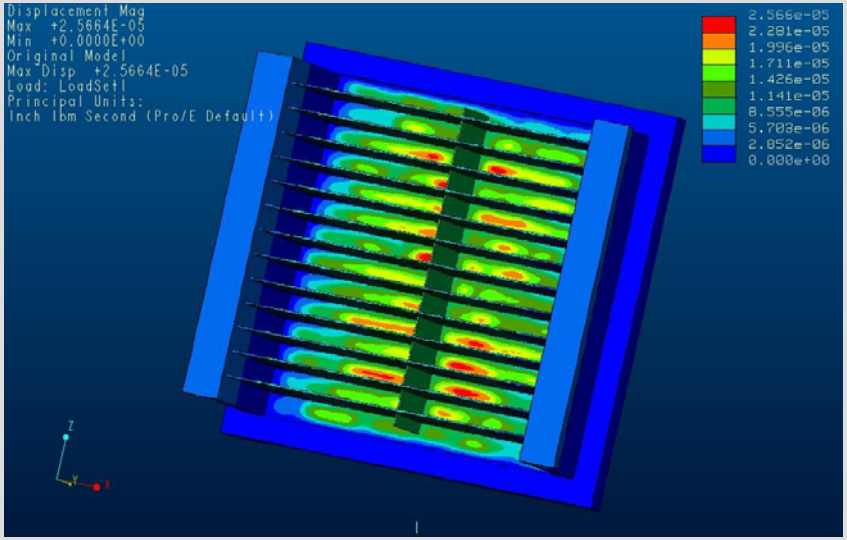


Solution

➢ Squashed tubes (PSDs are not available)

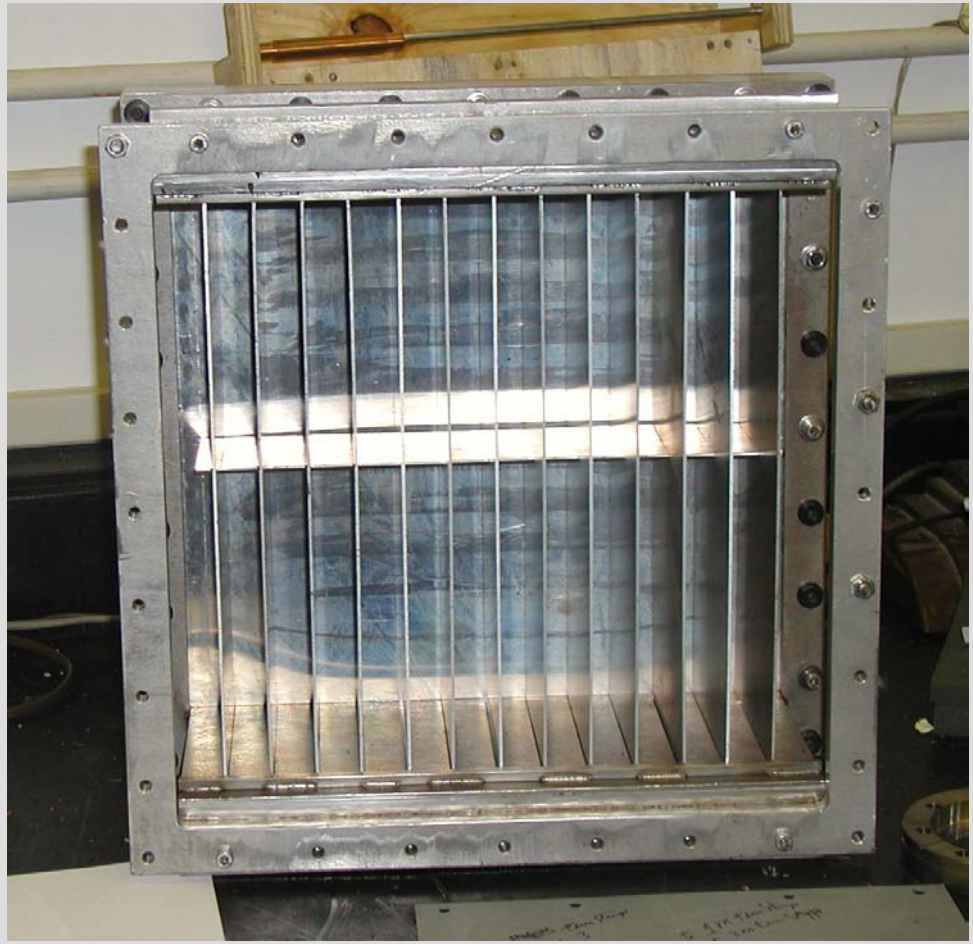
➢ Flat window detectors

Flat Window Detector



ProMechanica simulation of flat window deformations under pressure

1/16in-thick Aluminum7075 front window and support blades: observed deformation less than one millimeter under the pressure of six atmospheres inside the chamber



Multi-Pixel Detector

Saturation problem:

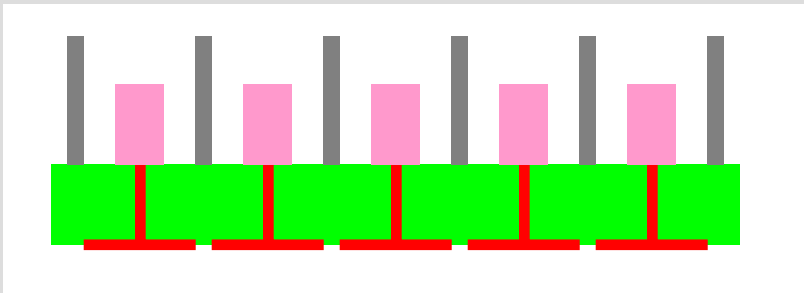
Can be solved using multi-pixel design

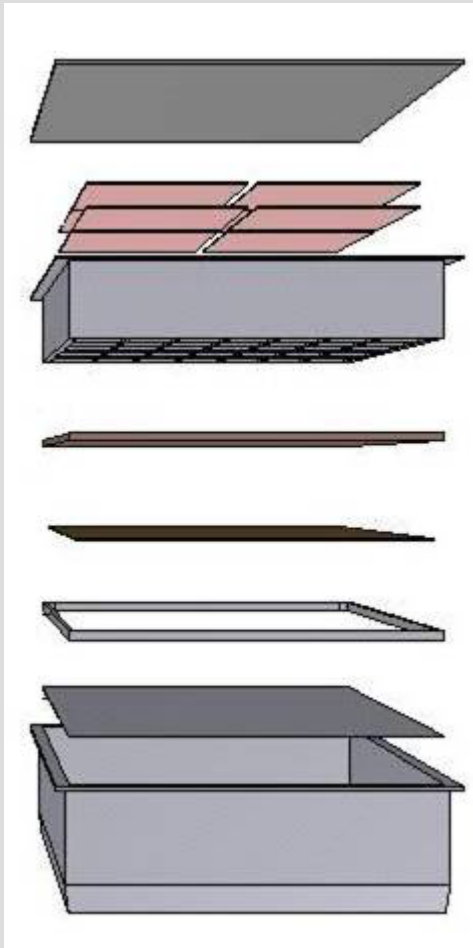
Problem: multiple feedthroughs

1cm^2 pixel on 1m^2 detector $\rightarrow$ 10,000 feedthroughs into the high pressure gas chamber

Possibility:

Low outgassing epoxy to make a plate with embedded cathodes and feedthroughs





Detector Development Capabilities

PSU Facilities

- **Development and Testing Lab**
  - Gas Filling System
  - Gas purification systems
  - Outgassing station
  - Test source
- **Breazeale Reactor**
  - 1 MW TRIGA
  - D_2O Moderator
  - $3x10^{13}$ n/cm^{2}sec
  - "Available on Demand"
- **Electronics**
  - Physics Department
  - Engineering (FPGA's, ASIC's…)
- **Machine Shops**
  - Physics, Engineering, ARL
- **Nanofabrication Facility**
  - Fabrication and characterization

High Energy Physics Group

- Jim Beatty – Auger
- Stephane Coutu – HEAT
- Steve Hepplemann – STAR
- Jim Whitmore - HERA

Detector Development at PSU

Conclusion

- Multi-tube cost-efficient LPSD banks are feasible
- High pressure gas detector chambers with thin front windows can be designed
- Multi-pixel chambers with multiple gas tight feedthroughs can be machined

Focused R&D effort:

- Detectors for CNCS
- Exploring multiple possibilities to determine costs
- CNCS detectors choice will be based on cost effectiveness and reliability
- We have required capabilities to develop and test various detector designs